# WIRELESS CHARGING AND COMMUNICATIONS SYSTEMS WITH DUAL-FREQUENCY PATCH ANTENNAS

## BACKGROUND

**[0001]** This relates generally to electronic devices and, more particularly, to electronic devices with wireless circuitry.

**[0002]** Electronic devices often include wireless circuitry. For example, cellular telephones, computers, and other devices often contain antennas and wireless transceivers for supporting wireless communications. Some devices include circuitry to support wireless charging operations.

**[0003]** Challenges can arise in implementing wireless charging and communications system. If care is not taken, sensitivity to antenna misalignment and other issues can make it difficult or impossible to achieve desired levels of performance when integrating antennas and other structures into devices of interest.

**[0004]** It would therefore be desirable to be able to provide systems with improved wireless circuitry.

## SUMMARY

**[0005]** An electronic device may be provided with wireless circuitry. The electronic device may use the wireless circuitry to transfer power wirelessly to external equipment or to communicate wirelessly with external equipment. Patch antennas may be used for wireless power transfer at microwave frequencies or other frequencies and may be used to support millimeter wave communications. The patch antennas may be used to form a beam steering array. The wireless circuitry may include adjustable circuitry to steer wireless signals associated with the antenna array.

**[0006]** The patch antennas may include one or more dual-frequency dual-polarization patch antennas. Each patch antenna may have a patch antenna resonating element that lies in a plane and a ground that lies in a different parallel plane. The patch antenna resonating element may be rectangular, may be oval, or may have other shapes. The patch antenna may have a first feed located along a first central axis of the patch antenna resonating element and a second feed located along a second central axis that is perpendicular to the first central axis. A shorting pin may be located at an intersecting point between the first and second axes.

**[0007]** Further features will be more apparent from the accompanying drawings and the following detailed description.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0008]** FIG. **1** is a perspective view of an illustrative system with wireless circuitry in accordance with an embodiment.

**[0009]** FIG. **2** is a schematic diagram of illustrative circuitry for use in electronic devices in a system with wireless capabilities in accordance with an embodiment.

**[0010]** FIG. **3** is a schematic diagram of illustrative wireless circuitry in accordance with an embodiment.

**[0011]** FIG. **4** is a diagram of an illustrative dipole antenna in accordance with an embodiment.

**[0012]** FIG. **5** is a perspective view of an illustrative patch antenna in accordance with an embodiment.

**[0013]** FIG. **6** is a side view of an illustrative patch antenna in accordance with an embodiment.

**[0014]** FIG. **7** is a perspective view of an illustrative patch antenna with dual ports in accordance with an embodiment.

**[0015]** FIG. **8** is a top view of an illustrative oval patch antenna in accordance with an embodiment.

**[0016]** FIG. **9** is a graph in which antenna efficiency has been plotted as a function of frequency for an antenna such as a dual-polarization dual-frequency patch antenna in accordance with an embodiment.

## DETAILED DESCRIPTION

**[0017]** A system of the type that may support wireless charging and wireless communications is shown in FIG. **1**. As shown in FIG. **1**, the system may include electronic devices such as electronic devices **10**A and **10**B. Devices such as **10**A and **10**B may communicate wirelessly over a wireless communications link. The wireless communications link may be a cellular telephone link (e.g., a wireless link at frequencies of 700 MHz to 2700 MHz or other suitable cellular telephone frequencies), may be a wireless local area network link operating at 2.4 GHz, 5 GHz, or other suitable wireless local area network frequencies, may involve millimeter wave communications (e.g., communications of the type sometimes referred to as extremely high frequency (EHF) communications that involve signals at 60 GHz or other frequencies between about 10 GHz and 400 GHz), may involve WiGig communications (millimeter wave IEEE 802.11 ad communications in a communications band at 60 GHz), or may involve communications at any other wireless communications frequencies (e.g., frequencies above 700 MHz, frequencies below 700 MHz, frequencies above 400 GHz, frequencies below 400 GHz, frequencies from 1-1000 MHz, frequencies above 100 MHz, frequencies above 500 MHz, frequencies above 1 GHz, frequencies from 1-400 GHz, frequencies below 100 GHz, or any other frequencies of interest). Power may also be transferred wirelessly between devices **10**A and **10**B at these frequencies or any other suitable frequencies. For example, device **10**A may transfer power wirelessly to device **10**B (e.g., to power device **10**B and/or to charge a battery in device **10**B). Wireless communications and wireless power transfer operations may be supported using wireless paths such as wireless path **106** of FIG. **1**.

**[0018]** Device **10**A and/or device **10**B may be a computing device such as a laptop computer, a computer monitor containing an embedded computer, a tablet computer, a cellular telephone, a media player, or other handheld or portable electronic device, a smaller device such as a wristwatch device, a pendant device, a headphone or earpiece device, a device embedded in eyeglasses or other equipment worn on a user's head, or other wearable or miniature device, a television, a computer display that does not contain an embedded computer, a gaming device, a navigation device, an embedded system such as a system in which electronic equipment with a display is mounted in a kiosk or automobile, equipment that implements the functionality of two or more of these devices, or other electronic equipment.

**[0019]** As shown in FIG. **1**, devices **10**A and **10**B may include wireless circuits such as circuit **104**A of device **10**A and circuit **104**B of device **10**B. Device **10**A may include one or more antennas such as antennas **40**A. Each of antennas **40**A may be coupled to a respective branch **102**A of wireless circuitry between circuit **104**A and that antenna **40**A. Each circuit branch **102**A may include a respective one of adjustable circuits **100**A (e.g., adjustable circuitry for